# Transmitted Frequency Range for Circuits In Broad-Band Systems

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IN utilizing the broad frequency ranges which the newer carrier systems can transmit the telephone engineer has a problem of choice in band width per channel to be allotted to speech currents. A sufficient width is vital to faithful speech reproduction; and desire for better telephone service always recommends an increase in band width over past practice. A reasonable balance, however, must obtain between various economic factors; and there must always be considered the relation between a proposed system and the other parts of the telephone plant, and also the trend of the art.

The message band widths and the channel spacing which have been chosen by the Bell System for various new systems are summarized and discussed in this paper. These systems are expected to play a large part in the future growth of its long distance plant; and the reasons underlying this choice may therefore be of general interest.

Different broad band systems are under development: A 12-channel system for use on open-wire lines employing frequencies up to 140,000 cycles, a 12-channel system for use on 19-gauge pairs in existing toll cables using frequencies up to 60,000 cycles, and a coaxial system capable of transmitting frequencies up to a million cycles or more, from which it is proposed to obtain 240 or more channels.

In the different systems noted above, terminal apparatus is employed which has many common features: The different channels are uniformly spaced at 4000-cycle intervals; the same band filters are used in the ultimate channel selecting circuits; and the derived voice circuit band widths are substantially identical for all channels of all systems. The transmission frequency characteristic of a single link of such systems, in accordance with present designs, is shown on Fig. 1. A curve for five similar links connected in tandem is also indicated. Based on a 10 db cutoff as compared with 1000-cycle transmission, a single-link band extends from approximately 150 to 3600 cycles, and a five-link band extends from about 200 to 3300 cycles.

There is, of course, no fixed relationship between the channel spacing and the frequency range of the derived voice-frequency circuit. This is largely a matter of economics in the design of a particular system.

The 4000-cycle channel spacing would permit obtaining a narrower band width with some simplification in the selecting circuits. With further development in selecting circuits, it is believed that it would permit obtaining a somewhat wider band or, if desired, a reduction in the cost of apparatus, maintaining the same band.

The band chosen initially for the new systems is believed to be a desirable and forward-looking step in the direction of improving the quality of speech transmission, a continuing trend which is as old as

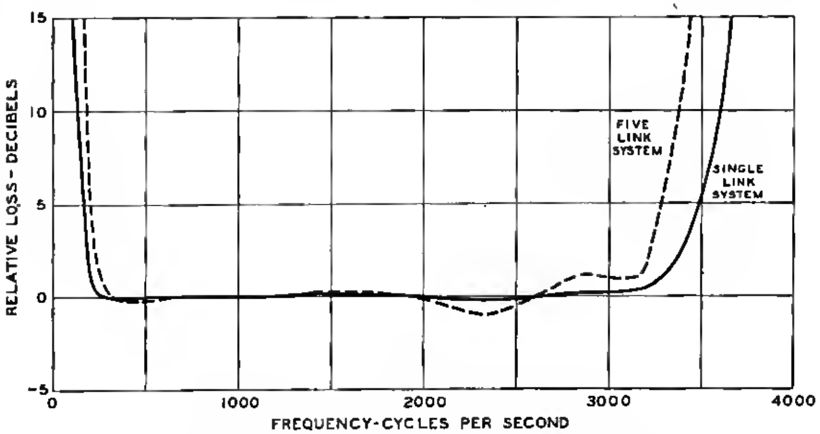


Fig. 1—Transmission frequency characteristics of broad-band systems.

telephony itself. Figure 2 shows typical band characteristics which mark the progress of transcontinental telephony since 1915. For shorter distances, the band widths have, of course, generally been wider than indicated on this series of curves. In the case of carrier systems the band depends on the number of links. The curve shown for 1937 is for the broad-band systems, estimated on the basis of a three-link connection.

The increase in band width is achieved without material increase in cost, since in situations which favor their use, broad-band systems provide circuits which are substantially more economical than other alternatives, and the improvement can therefore be obtained by giving up only a small portion of the savings which the systems themselves make possible. If, as in some older types of systems, it had been chosen to maintain a standard of 250 to 2750 cycles for a single-link connection in the broad band systems, this could have been accomplished by the use of a channel frequency spacing of about 3000 cycles. The wider transmission band is therefore obtained by a sacrifice in

the ratio of approximately 3:4 in the number of channels obtained within a given frequency range. However, this does not mean a 4:3 increase in the cost per circuit. The amount is considerably less than this—depending somewhat on the type of system. In the proposed coaxial system, which appears to be a favorable example, where the attenuation increases roughly as the square root of the frequency, a frequency band increased by one-third means that for repeaters of a given type and amplification the number of repeaters is multiplied by approximately $\sqrt{\frac{4}{3}}$; that is to say, approximately 15 per cent more repeaters are required. Furthermore, the line and terminal apparatus costs are not changed in a case of this kind, and since they constitute a major part of the total cost, the net increase in cost for the wider

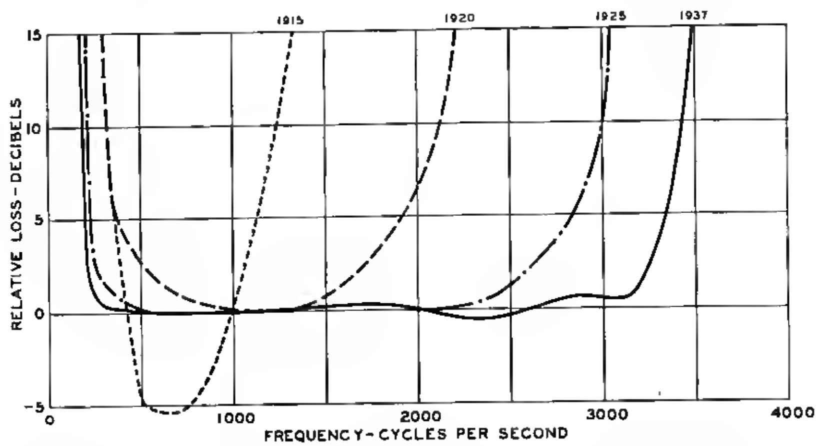


Fig. 2—Representative transmission frequency characteristics of 3000-mile toll circuits.

band width will be considerably less than 15 per cent—about five per cent in the case of the longer systems where the terminal apparatus costs are a small factor, and only a per cent or two in the case of the very short systems where the terminal apparatus costs predominate.

In the ideal case, using substantially perfect transmitters and receivers, articulation is improved as the upper limit in frequency transmission is raised, as shown in Fig. 3. The increase in transmission performance, which a step from 2750 to 3300 cycles, or 3600 cycles for a single link, makes possible, is evidently still on the part of the band width-articulation relationship where a measurable increase in articulation may be expected. An improvement in band width accordingly reduces the effort needed to interchange ideas, since fewer repe-

titions occur and attention can be somewhat relaxed. It also enhances the naturalness of the received speech, and so makes the conversation more pleasing as well as easier. It should be noted also that the proposed broad-band systems will transmit frequencies approximately 50 to 100 cycles lower than earlier systems, which, while not contributing appreciably to articulation, has the effect of increasing naturalness.

When applied in the telephone plant, the resultant effect of a given increase in band width will of course depend on the other parts of the circuit, and the transmission characteristics of the transmitters and receivers. Improved transmitters and receivers are now being applied

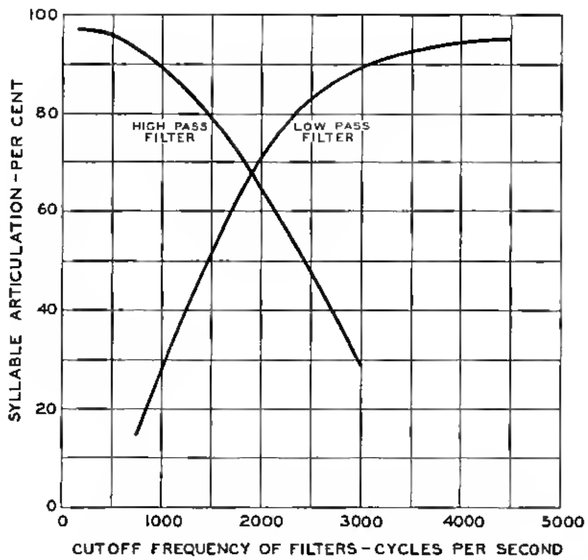


Fig. 3—Effect of cutoff frequency on syllable articulation.

rapidly in the Bell System. They have much better transmission characteristics than earlier types and an effective upper frequency of transmission for the new station set which is well above 3000 cycles, as shown on Fig. 4.

The toll connecting trunks are important links in a typical overall connection, and here also there has been a continued trend to provide wider band circuits. Figure 5 shows the transmission frequency characteristics of representative types of toll connecting trunks which are being commonly installed at present. Both non-loaded and loaded trunks are shown on the figure. Of course, in the non-loaded case, there is no definite cutoff frequency. The curve for the loaded trunk

shows a reasonably long trunk having a 5 db loss at 1000 cycles (6.4 miles). In practice, of course, the trunk length may vary from a

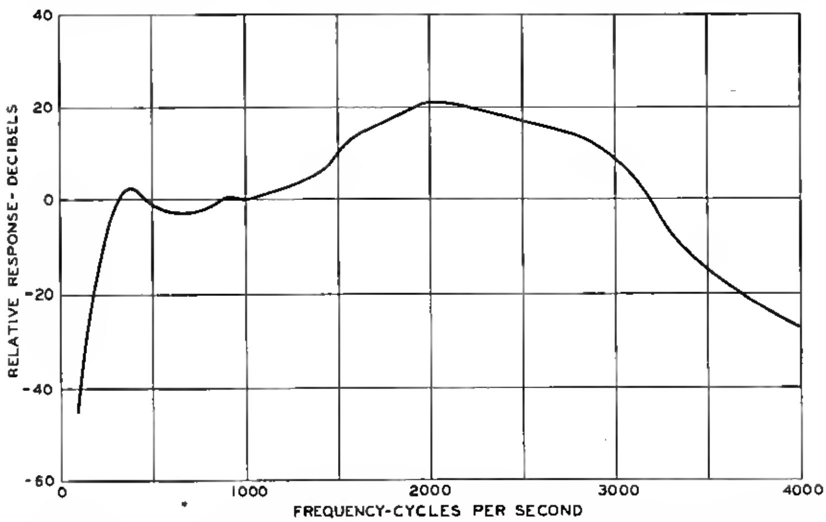


Fig. 4—New station-set characteristics (including two one-mile 24-gauge loops connected by distortionless trunk).

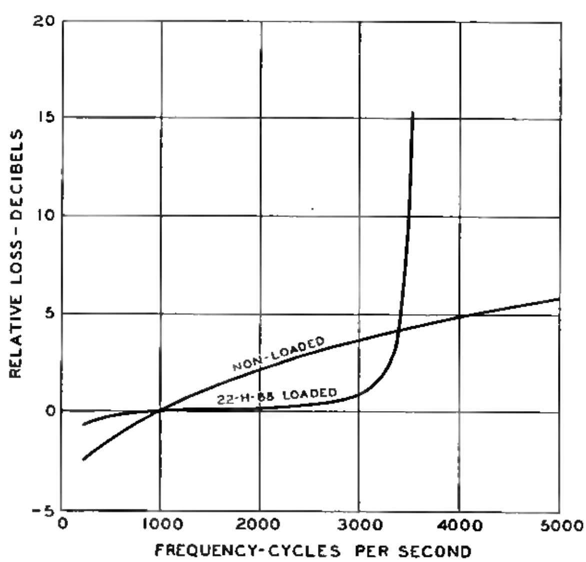


Fig. 5—Toll connecting trunk characteristics.

fraction of a mile to 10 miles or more, with a corresponding effect on the transmission characteristic. It will be noted that the effective

cutoff of the loaded trunk shown is about 3500 cycles based on a 10 db cutoff point. Other types of loading, which will also be employed, will have still higher cutoff points. Evidently the band widths of the broad-band circuits, toll connecting trunks, and new station sets are well matched.

Laboratory and field tests have been made with circuits simulating the cutoff of the new broad-band systems and using various types of station sets, including the new standard. These indicate that raising the cutoff from 2750 cycles to 3600 cycles is equivalent to making a reduction of 3 to 4 db in the net overall loss of the circuit. Raising the cutoff from 2750 cycles to 3300 cycles is equivalent to a lesser reduction. With older types of instruments which reproduce speech less faithfully, this difference is also less, and of course, with instruments providing transmission up to considerably higher frequencies, the difference is greater.

It will be appreciated, of course, that the wider speech band which will be made available in the new broad-band systems will not be fully effective in all telephone connections unless other toll circuits and toll connecting trunks and station sets are provided with improved transmission frequency characteristics. From a practical standpoint it is obvious that in a large telephone plant improvements cannot be made in all parts at one time. They must be introduced gradually as new systems and apparatus are applied, and with a far-sighted concern for future trends.